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## ON "RETIRING" AND "ADVANCING" COLORS

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Doubtless it has often been noted that various colors in the same plane do not appear to be in the same plane. The artist speaks of retiring and advancing colors; and some painters who are fortunate in being acquainted with the scientific facts of color have utilized this phenomenon in attempts to create the illusion of the third dimension in paintings. The phenomenon is quite strikingly apparent to the author when viewing the projected image of a lantern slide on which there are words in various colors as is commonly the case with slides used for advertising purposes. Never having seen any quantitative data on the subject, it appeared of interest to ascertain the magnitude of the effect and whether or not the impression was generally the same for all observers. The work is by no means complete and may cover ground that has already been covered but a search has not yielded any information that would indicate this. This work has been reported in abstract<sup>1</sup> under the title of "stereoscopic" colors. It appears that this describes the phenomenon and its practical uses quite satisfactorily.

The apparatus consisted of two wooden boxes, each containing a tungsten lamp and each equipped in front with an aperture covered with opal glass. Before the diffusing glass in one box were placed a red filter (fairly high purity) and an opaque card in which a plain letter X was cut. The other box was similarly equipped with a blue filter (fair purity with no red transmission) and a diaphragm on which a plain letter E was cut. The height of the letters was 2.2 cm. and the width was 1.5 cm. The boxes, which were painted white inside and black outside, were arranged on tracks side by side so that they could be moved independently to and fro by the observer by means of strings and pulleys. In a dark-room these two colored letters stood out in space; and, while one was kept in a fixed position, it was possible for the observer to move the other to and fro until the two appeared

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<sup>1</sup> *Jour. Frank. Inst.* 183, 1917, p. 773.

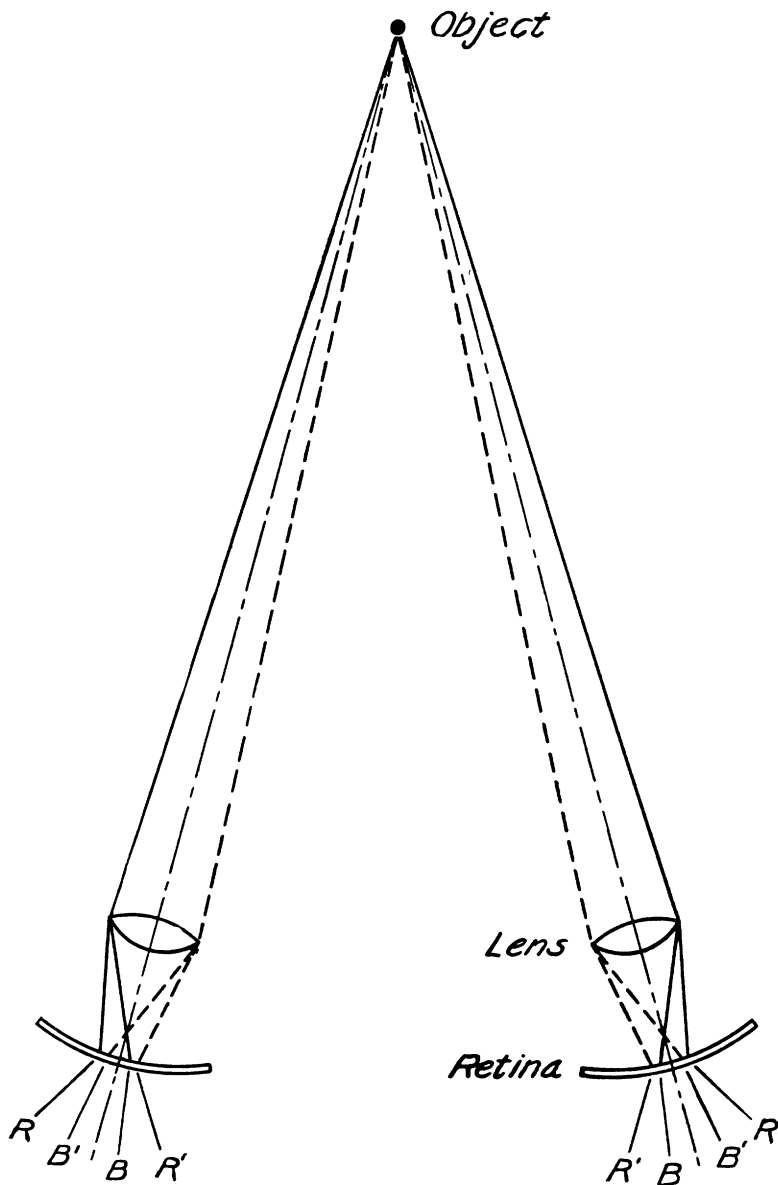


FIG. 1.—Illustrating a possible explanation of 'stereoscopic' colors.

in the same plane. In obtaining the data given in the table, the red X was moved. The observer was seated at various stations from 2.5 to 7.25 meters from the fixed blue E. At each station at least ten independent settings were made in a series. None of the observers, with the exception of *M. L.*, were acquainted with the phenomenon under consideration.

In the table, data are presented for nine observers. At the top of each column is shown the distance in meters of the observer's eyes from the blue E; and the figures in the columns indicate the distance in centimeters which the red X was moved behind (+) or in front of (—) the blue E in order that the two would appear in the same plane.

<i>Total distance in metres</i>	2.5 <i>cm.</i>	4 <i>cm.</i>	5 <i>cm.</i>	6 <i>cm.</i>	7.25 <i>cm.</i>
<i>M. L.</i> .....	2.8	16.0	24.6	39.8	57.7
<i>H. K.</i> .....	4.8	13.7	21.0	31.7	46.2
<i>F. G.</i> .....	1.6	5.3	7.6	5.3	12.5
<i>P. H.</i> .....	3.1	15.1	8.4	35.6	49.5
<i>L. M.</i> .....	2.6	4.5	13.4	14.4	18.3
<i>E. K.</i> .....	7.4	28.2	50.9	22.6	71.7
<i>H. P.</i> .....	5.1	2.4		23.2	17.4
<i>L. C.</i> .....	—0.4	—1.9	1.4	8.9	—2.7
<i>G. H.</i> .....	—7.4	—18.5	—34.0	—37.6	—49.7

It is seen that in most cases it was necessary to move the red X farther away than the blue E in order to make both appear in the same vertical plane perpendicular to the line of sight; and that this distance generally increased with the distance of the observer's eyes. It is quite possible that through training the results for a given observer would become more consistent but even the degree of consistency indicated in the data obtained from observers, who until after the experiments were not acquainted with the phenomenon, appears quite striking. The phenomenon is somewhat fluctuating but the results for a given observer usually indicate a definite trend. Computations from the data by *M. L.* indicate that chromatic aberration in the eye could account for the effect but the negative values for the last two observers and other considerations complicate this explanation.

Observer *M. L.* performed the following experiments, the results of which were confirmed by other "positive" observers who were used. If the two letters were placed in the same plane they did not appear in the same plane but, by nearly closing the eyelids, they appeared to move into the same plane. Similarly when the two objects were placed so that they *appeared* in the same plane, on nearly closing the eyelids, the

red X appeared to move into its true position; that is, back of the blue E. When two very small artificial pupils were placed respectively before each eye the blue E could be made to appear either behind or before the red X by moving the pupils farther apart or nearer together. It appeared that, for those who normally saw the red X in front of the blue E, when the small artificial pupils were moved closer together the blue E apparently moved forward very strikingly; when the pupils were separated a trifle more the blue E moved backward. Through these small artificial pupils both images appeared simultaneously in focus at all times, which of course was not true with the natural pupils. On turning the head slightly, results similar to the preceding were obtained. Differences in relative brightness and shape of the colored characters seemed to influence the magnitude of the results somewhat but the effect was never reversed. The effect could not be observed with certainty with one eye.

In order to give an idea of the consistency of the individual settings the mean variation from the mean was computed for a number of cases. In general this was higher for the inexperienced observers but from *M. L.* it was 0.39 cm. (14 per cent.) at the 2.5 meter distance. It decreased with the distance of the observing station and was 1.27 cm. (2.7 per cent.) at the 7.25 meter station. This indicates that the phenomenon was very definite.

A complete explanation can hardly be justified on the basis of the present data but owing to an indefinite interruption of the work an hypothesis will be briefly presented. It appears possible that the different refractive indices of the eye media for radiant energy may play a part in causing this effect. These may account for a displacement of the colored images which gives rise to the "stereoscopic" effect quite in the same manner as in ordinary vision. The point may be brought out more clearly by means of Fig. 1. Assume that only the temporal portions of the eye lenses are used; then if the object is blue, the images will be found at B (solid lines) and if the object is red, the images will fall at R. Naturally the blue object will seem to be farther away than a red object in the same position since these respective positions of the images generally correspond to far and near objects. If the nasal portions of the lenses are considered the dashed lines may be referred to, the blue and red images falling at B' and R' and the reverse effect is obtained. In this case the effect will be reversed thus accounting for the results obtained by moving the small artificial pupils further apart or nearer to-

gether as already discussed. The figure is only diagrammatic and does not pretend to illustrate the entire condition accurately. If such an explanation is correct or even partially correct the differences between the results obtained by the observers will likely be explained partly by differences in the shapes and relations of the various parts of the eyes such as curvatures, eccentricity of pupils, refractive indices, etc.

It is shown by these data that colors do actually 'retire' and 'advance'; and that in general blue is retiring and red is advancing. If the explanation which has been suggested is correct the arrangement of hues in the spectrum is a true index. Although employing impure colors the testimony of the artist supports this conclusion. This explanation appears quite satisfactory, however, the author does not wish to emphasize it too much at the present time. Unfortunately the strikingly 'negative' observer, *G. H.*, is not available so that further inquiry with this definite exception of the group is not possible at present.

The author is indebted to Mr. H. H. Kirby for assistance in obtaining these data.